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(54) Motion compensated image interpolation

(57) A motion compensated image interpolation system is described in which a mechanism is provided for the adjustment of control values to the apparatus to reduce artifacts in the interpolation output images. Output interpolated images that are substantially temporally coincident with input images are subtracted from the input images. If the interpolation process is accurate, then there should be no difference. A difference that is present can form the basis of an error signal that may be used in a feedback process to adjust control inputs to the apparatus. In some embodiments the interpolation images that are temporally coincident with input images will be detected as and when they occur for use in performing this analysis. In other embodiments, the output interpolated images can undergo an additional interpolation process to be projected back to the input image times to provide a continuous error signal. The error signal may control parameters such as a threshold used in alias rejection in correlation surface analysis or search block size control in correlation surface generation.

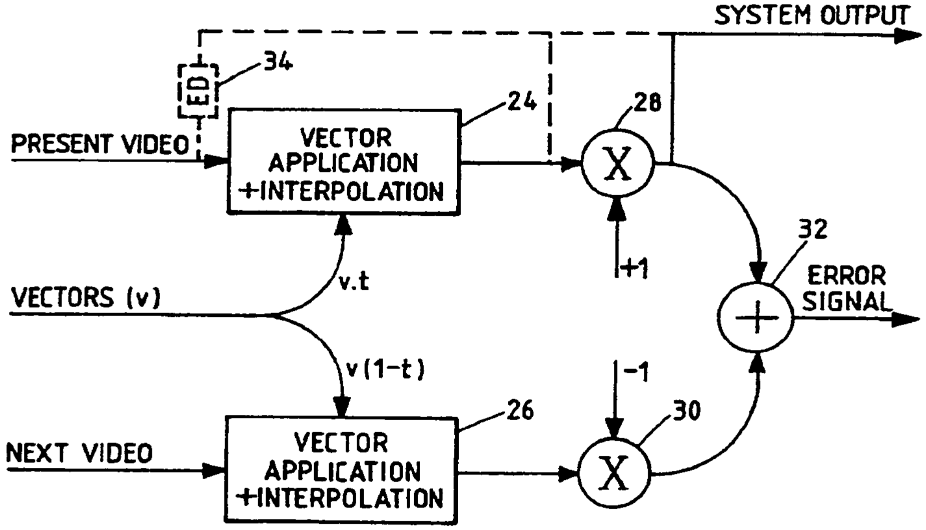

Fig.3

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

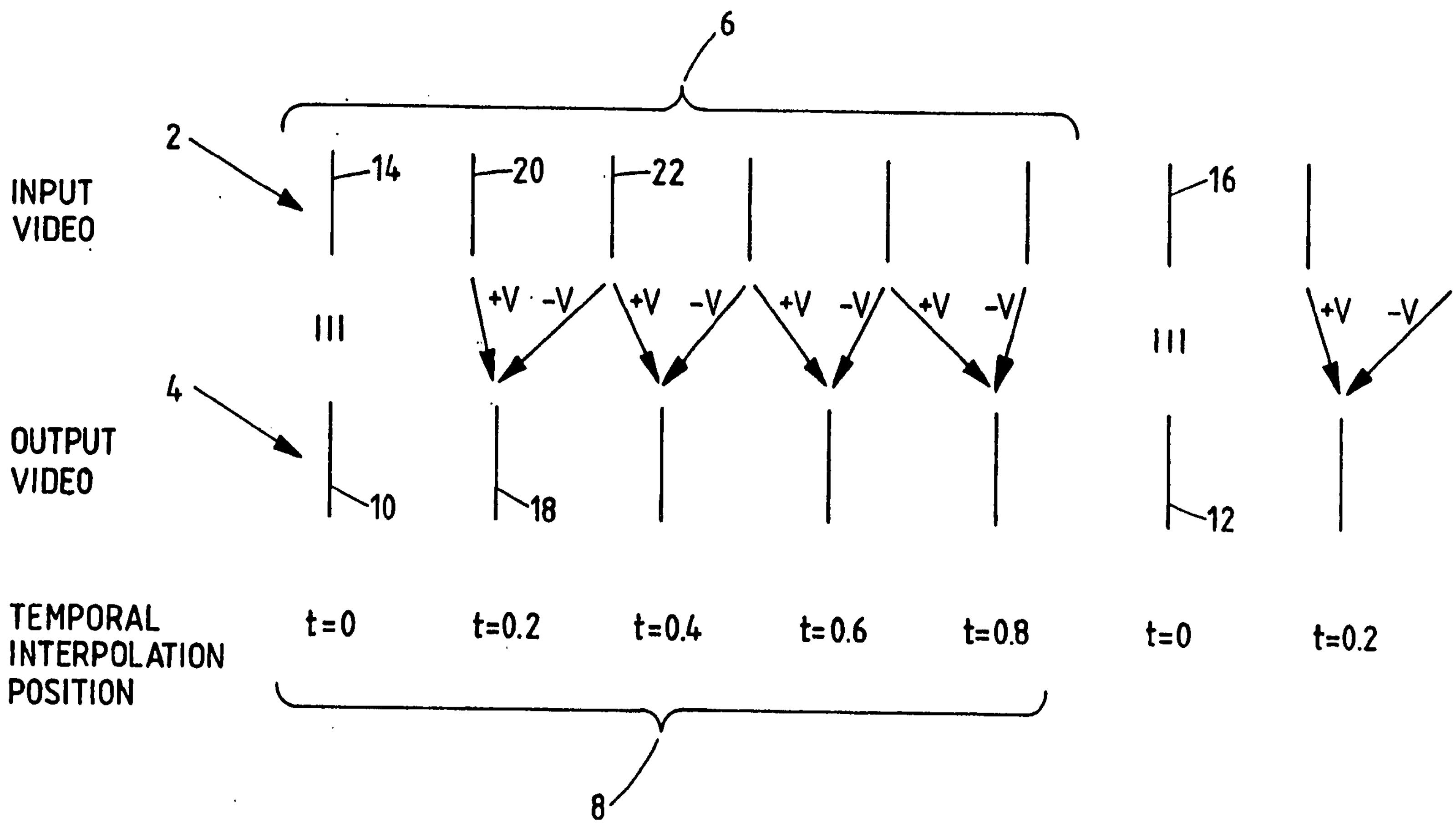
INPUT VIDEO
OUTPUT VIDEO
TEMPORAL INTERPOLATION POSITION
2
4
6
8
14
20
22
16
10
18
12
+V
-V
t=0
t=0.2
t=0.4
t=0.6
t=0.8
t=0
t=0.2

Fig.1

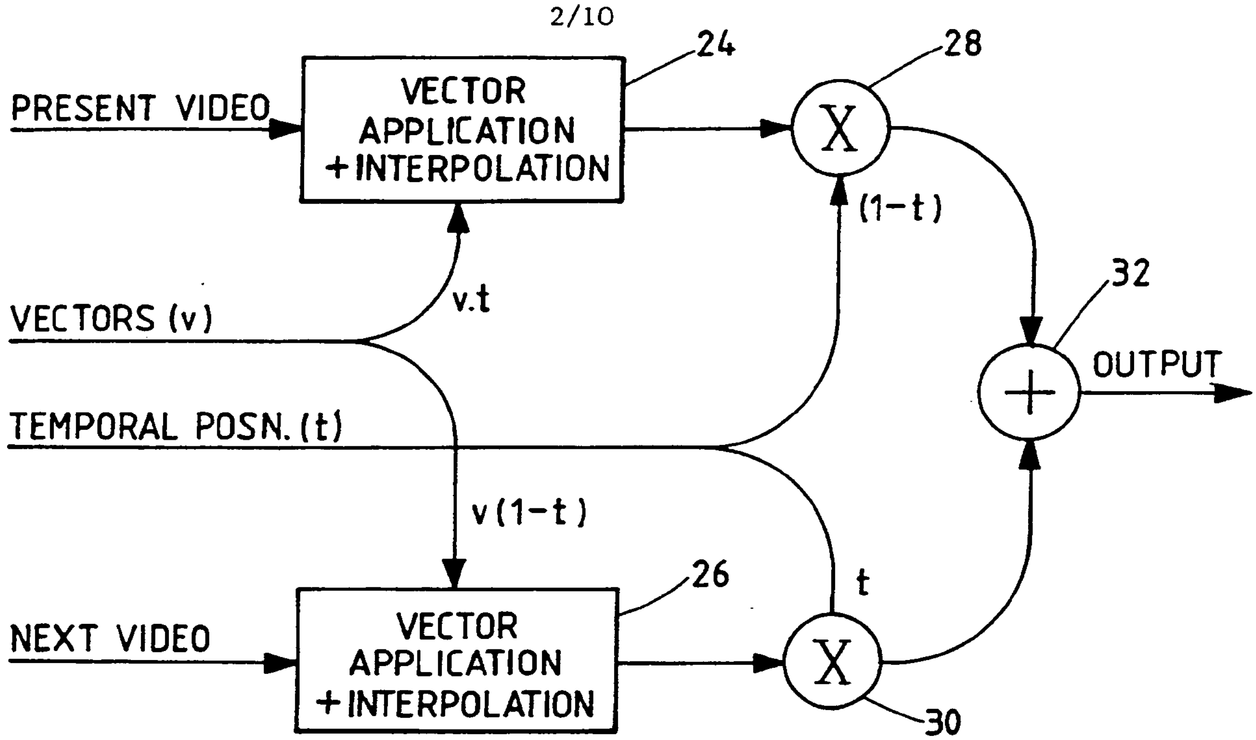
PRESENT VIDEO
VECTOR APPLICATION + INTERPOLATION
24
28
X
(1-t)
32
VECTORS (v)
v.t
OUTPUT
TEMPORAL POSN. (t)
v(1-t)
t
26
NEXT VIDEO
VECTOR APPLICATION + INTERPOLATION
X
30

Fig.2

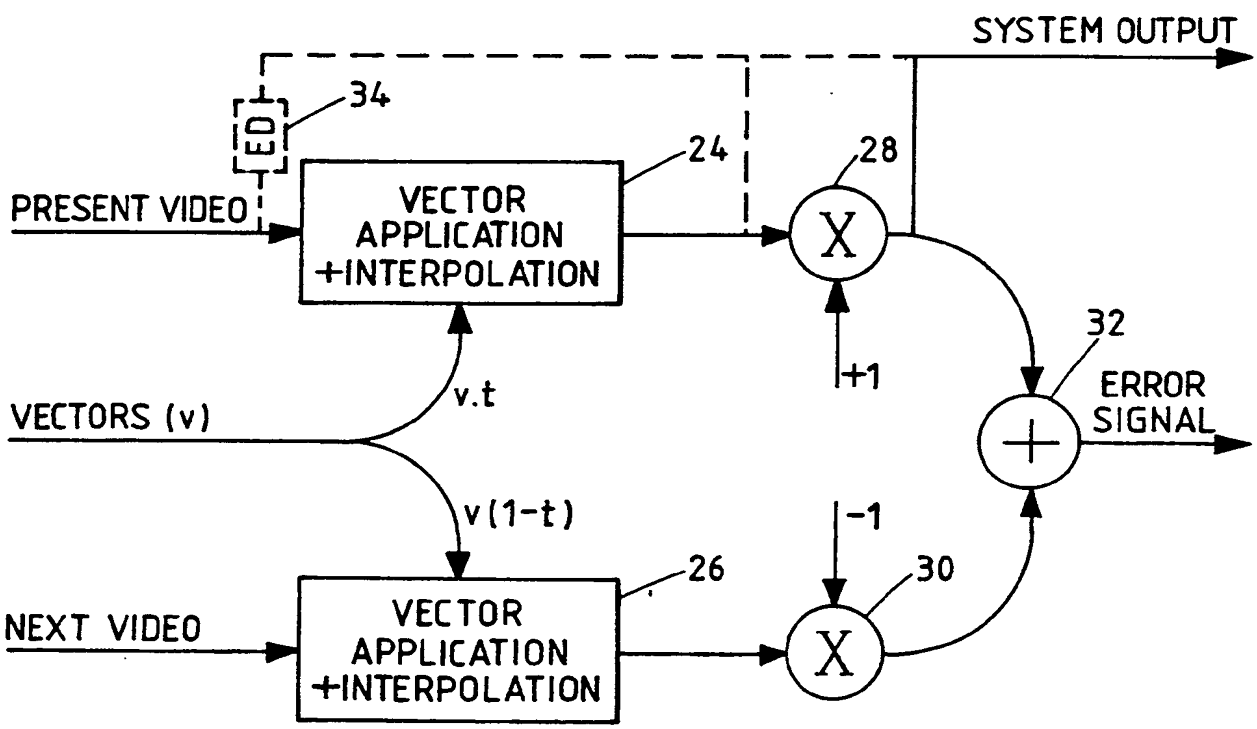
SYSTEM OUTPUT
34
ED
24
28
PRESENT VIDEO
VECTOR APPLICATION +INTERPOLATION
X
32
+1
VECTORS (v)
v.t
ERROR SIGNAL
v(1-t)
-1
26
30
NEXT VIDEO
VECTOR APPLICATION +INTERPOLATION
X

Fig.3

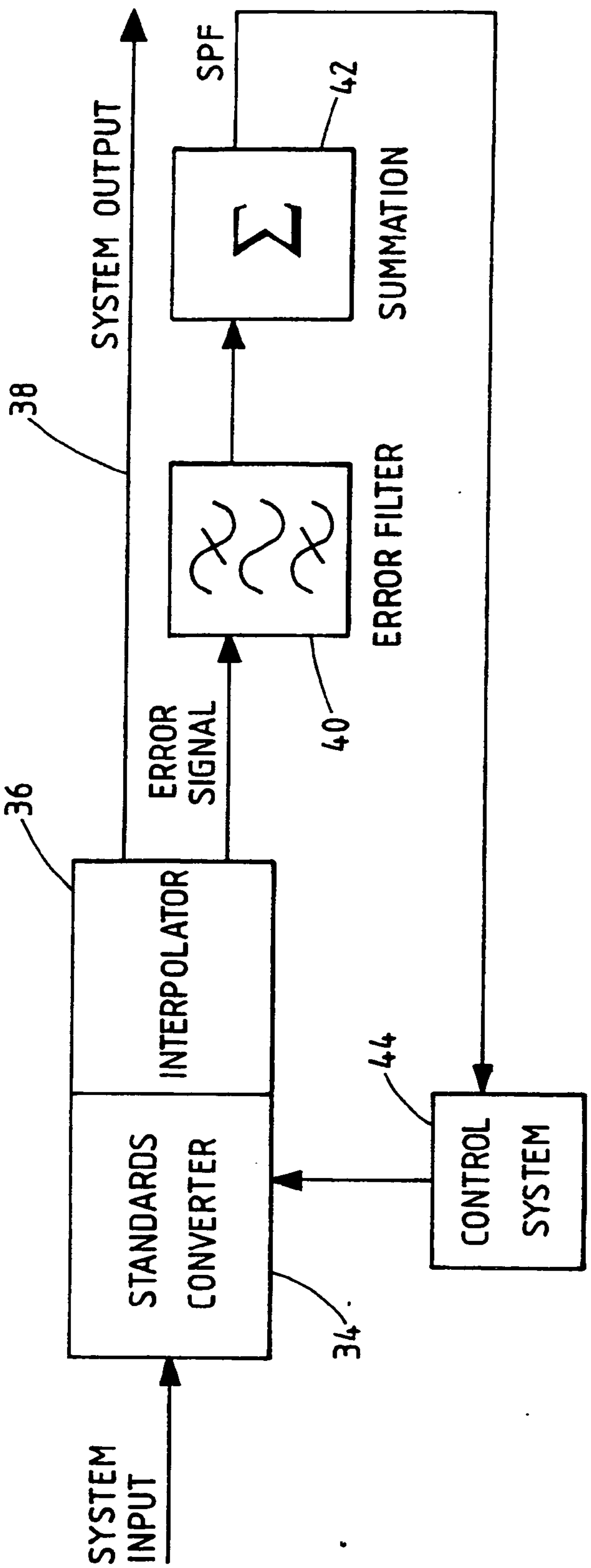
SYSTEM INPUT
STANDARDS CONVERTER
34
INTERPOLATOR
36
38
SYSTEM OUTPUT
ERROR SIGNAL
ERROR FILTER
40
SUMMATION
42
SPF
CONTROL SYSTEM
44

Fig.4

FRAME	0	1	2	3	4	5	6	7	8	9	10	11	12
SETTINGS	α	α	α	α	α	$\alpha+\delta$	α	α	α	α	$\alpha-\delta$	β	β
TEMP. POSN.	0	0.2	0.4	0.6	0.8	0	0.2	0.4	0.6	0.8	0	0.2	0.4

SPF_0 SPF_5 SPF_{10}

$$\beta = \text{BEST SETTINGS OF} \begin{cases} \alpha \\ \alpha+\delta \\ \alpha-\delta \end{cases}$$

Fig.5

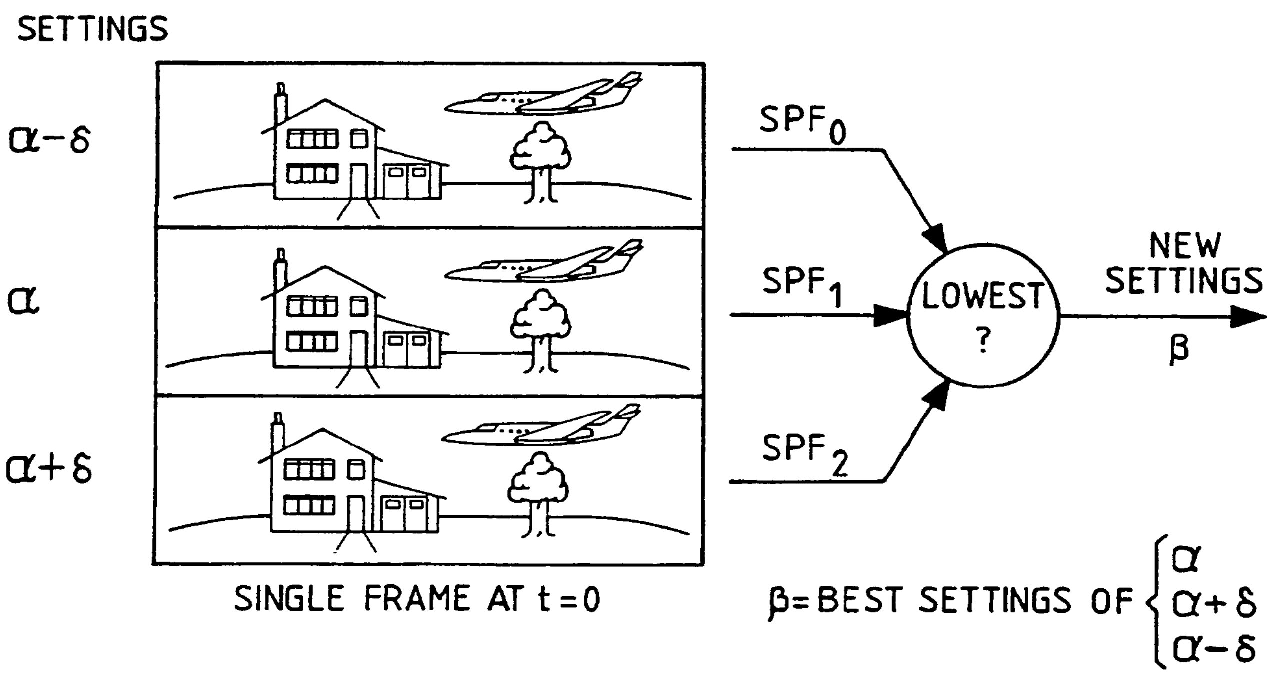

Fig.6

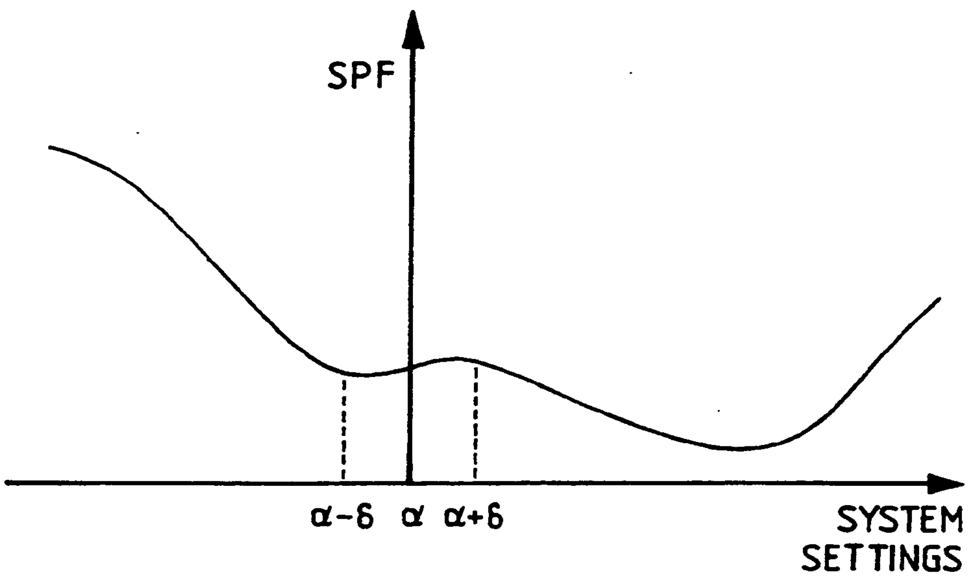

Fig.7

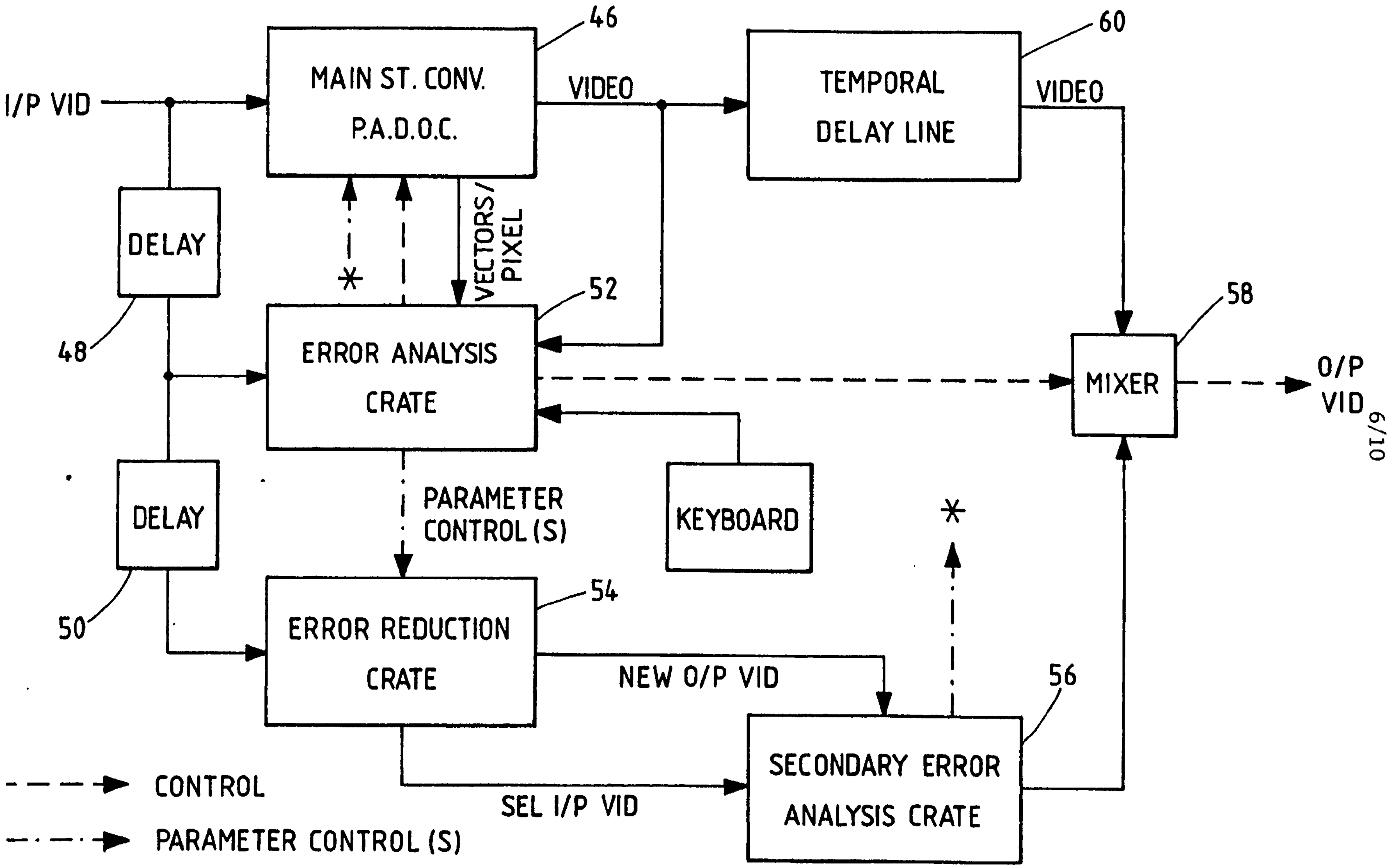
I/P VID
MAIN ST. CONV.
P.A.D.O.C.
46
VIDEO
TEMPORAL
DELAY LINE
60
VIDEO
DELAY
48
VECTORS/
PIXEL
*
ERROR ANALYSIS
CRATE
52
MIXER
58
O/P
VID
DELAY
50
PARAMETER
CONTROL (S)
KEYBOARD
*
ERROR REDUCTION
CRATE
54
NEW O/P VID
56
SECONDARY ERROR
ANALYSIS CRATE
SEL I/P VID
CONTROL
PARAMETER CONTROL (S)

Fig.8

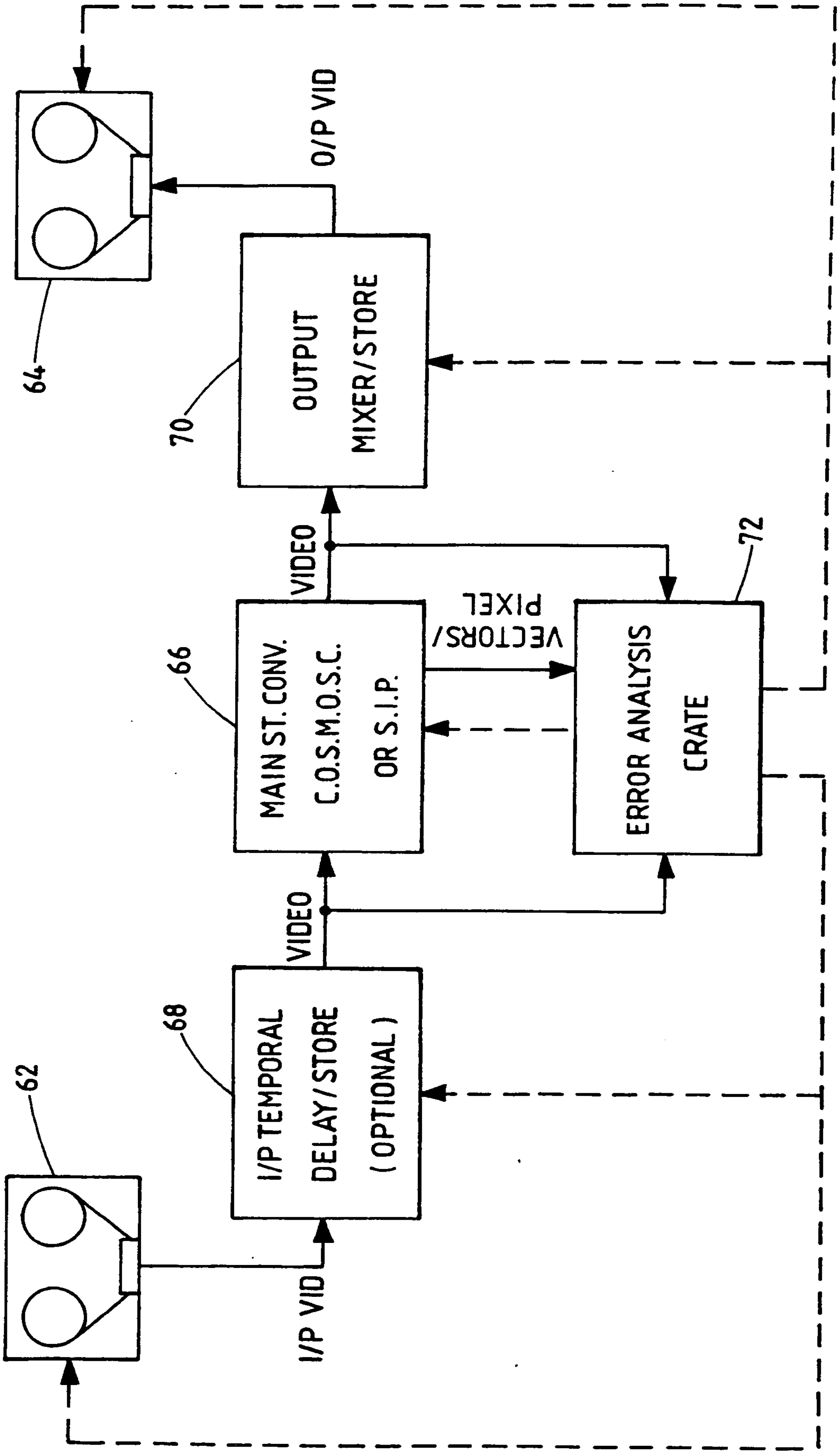
64
O/P VID
70
OUTPUT
MIXER/STORE
VIDEO
VECTORS/
PIXEL
72
66
MAIN ST. CONV.
C.O.S.M.O.S.C.
OR S.I.P.
ERROR ANALYSIS
CRATE
VIDEO
68
I/P TEMPORAL
DELAY/STORE
(OPTIONAL)
62
I/P VID

Fig. 9

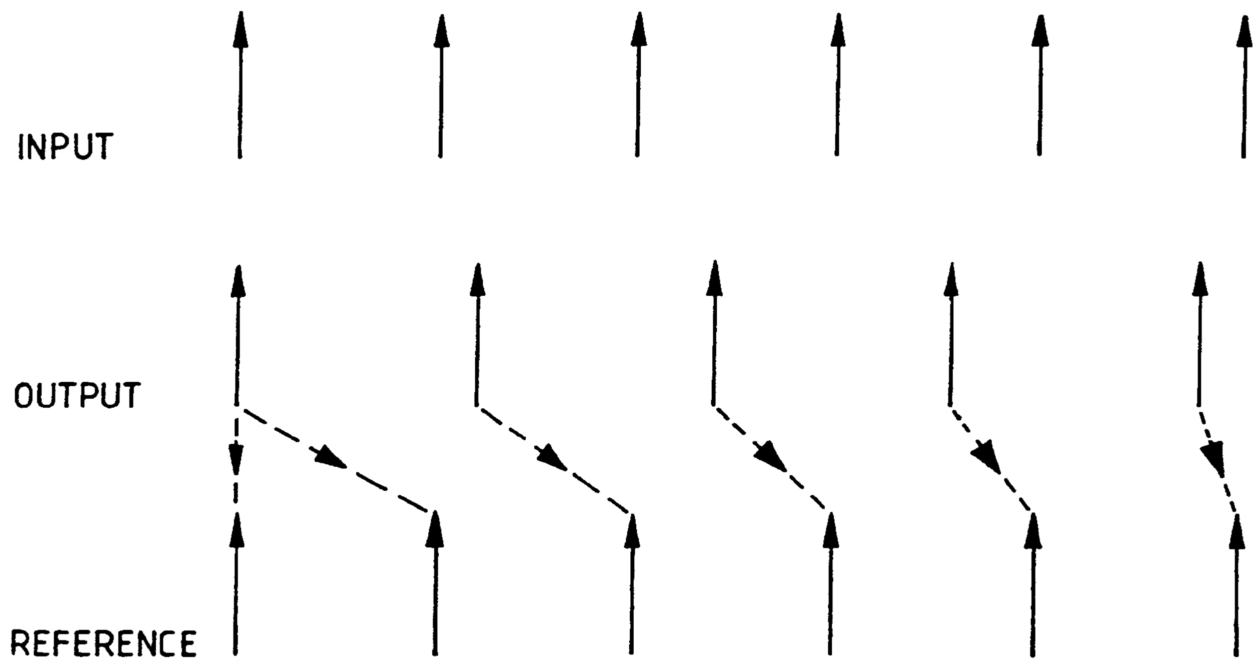

Fig.10

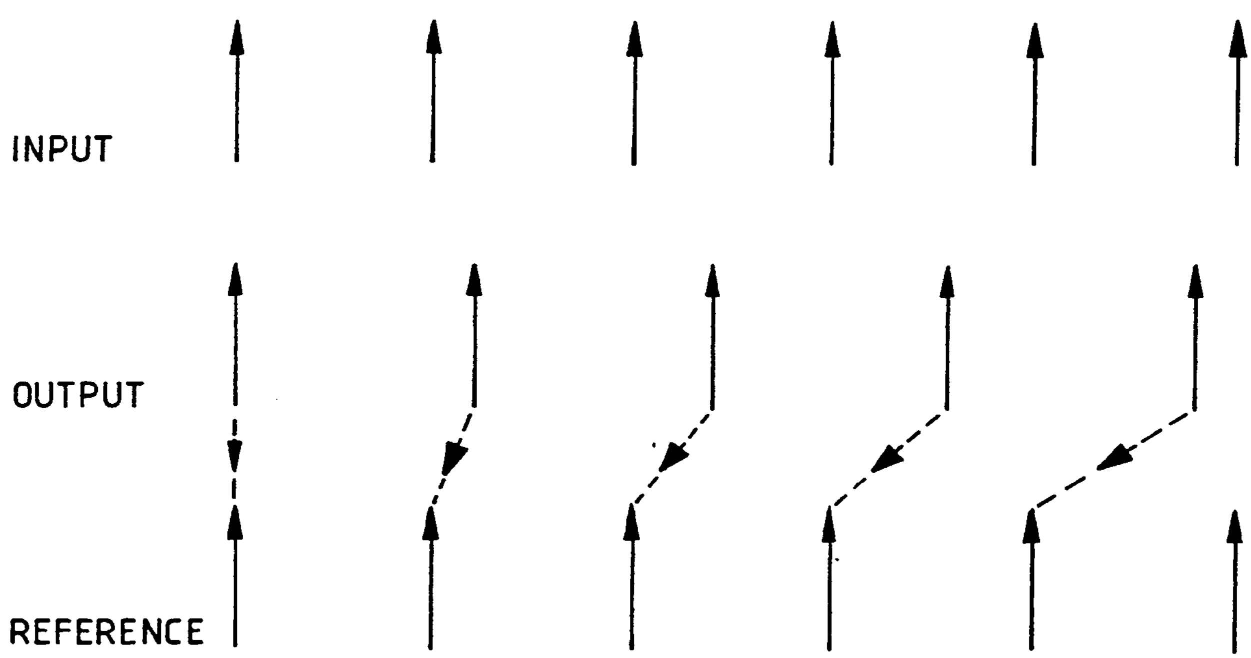

Fig.11

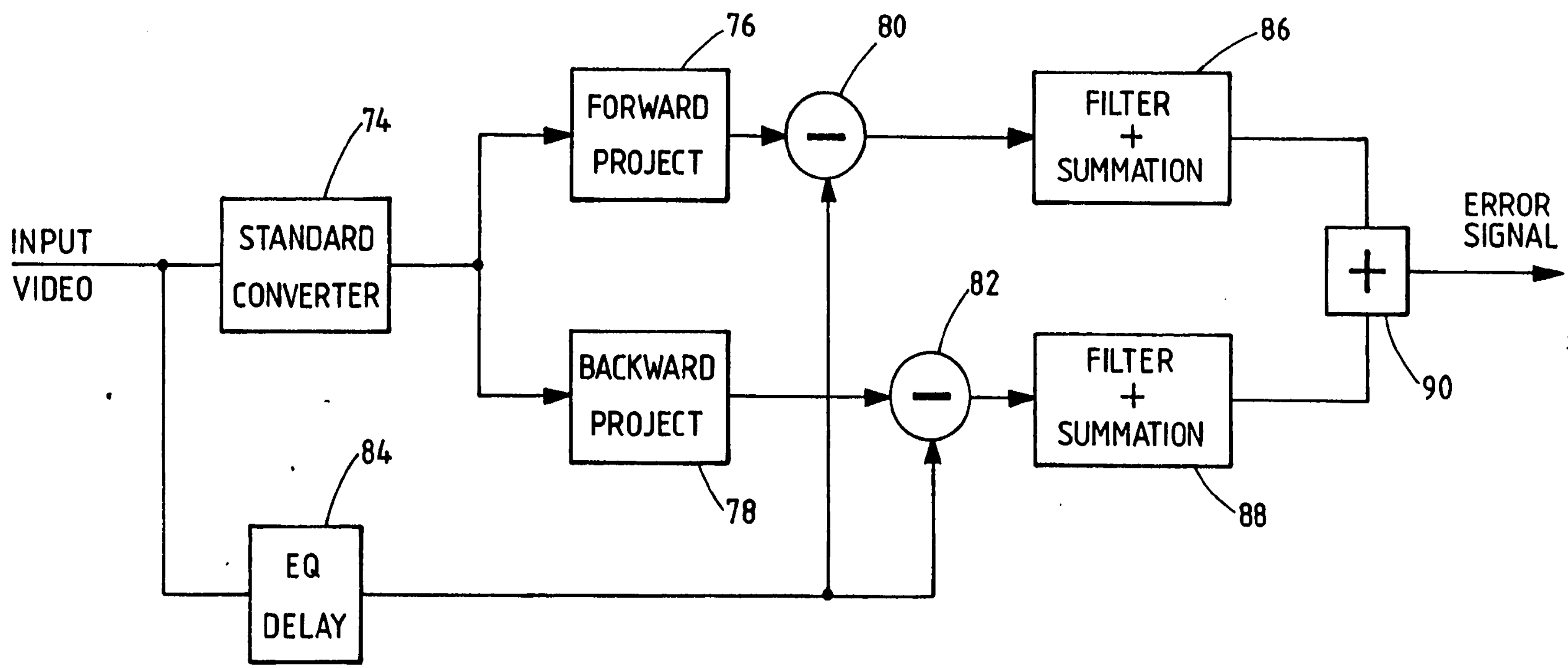
INPUT
VIDEO
74
STANDARD CONVERTER
84
EQ DELAY
76
FORWARD PROJECT
78
BACKWARD PROJECT
80
82
86
FILTER + SUMMATION
88
FILTER + SUMMATION
90
ERROR SIGNAL

Fig.12

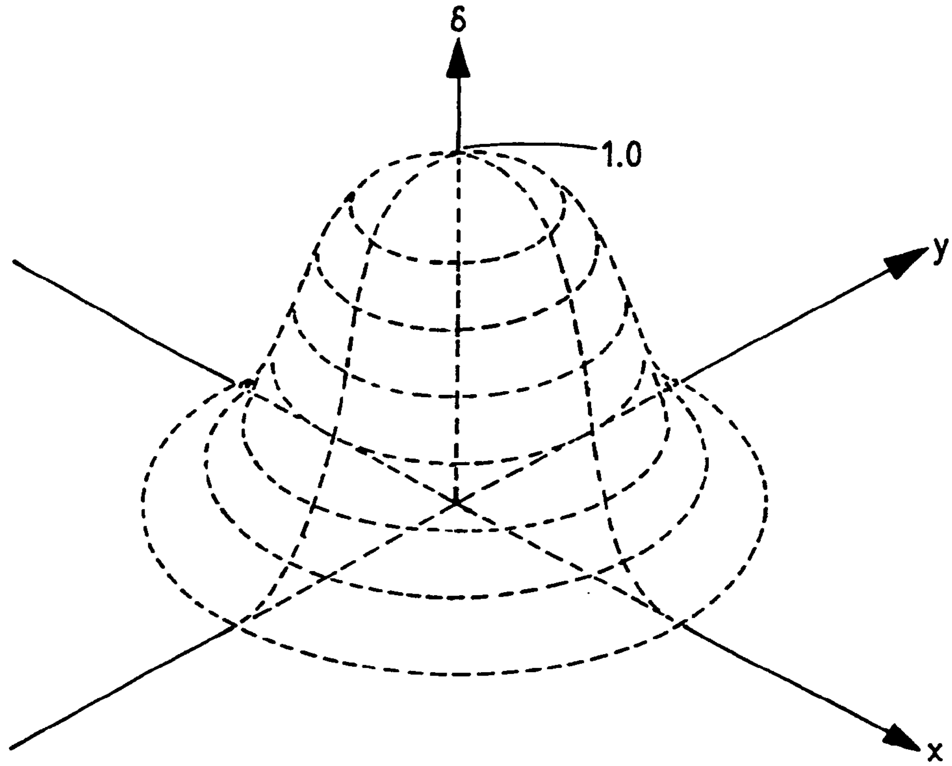

Fig.13

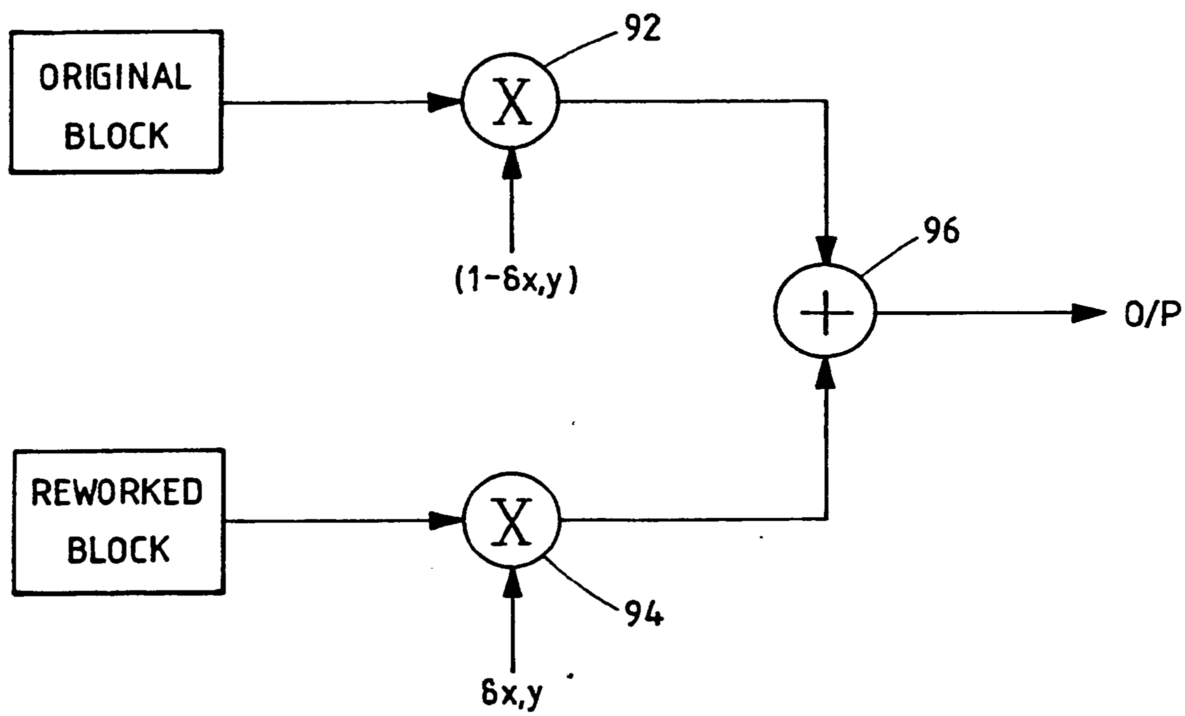

Fig.14

MOTION COMPENSATED IMAGE INTERPOLATION

This invention relates to the field of motion compensated image interpolation. More particularly, this invention relates to motion compensated image interpolation in which output images at an output rate are generated from input images at a input rate that is different from the output rate.

Motion compensated image interpolation for purposes such as standards conversion is known, e.g. from film to television or from one television format to another. An example of such a system is described in British Published Patent Application GB-A-2,231,749 (Sony Corporation). Known motion compensated standards converters suffer from motion artifacts. These artifacts can be controlled by the adjustment of system parameters such as threshold and conversion modes. An operator is required to study the output video for errors and then steer or alter the system parameters accordingly. This is expensive and is not satisfactory for on-line operation.

This invention addresses the problem of more effectively controlling the system parameters to improve output image quality.

Viewed from one aspect this invention provides apparatus for generating motion compensated output images at an output rate from input images at an input rate, said output rate being different from said input rate, said apparatus comprising:

an output interpolator for generating interpolated images at said output rate from temporally adjacent input images in dependence upon image motion vectors;

means for subtracting at least a portion of a non motion compensated image, taken from a corresponding input image, from at least a portion of an substantially temporally coincident test interpolated image to form an error signal; and

means for adjusting control inputs to said apparatus in dependence upon said error signal.

The invention recognises that an automatic feedback path may be provided by comparing an interpolated image with a temporally coincident non motion compensated image taken from an input image. Any differences between these two images are likely to be due to any artifacts introduced by the motion compensated interpolation process.

Thus, deriving an error signal from the difference between the two images provides a measure of the amount of artifacts in the image that can then be used as a feedback signal to adjust control inputs to the apparatus. The input images effectively used as reference signals which the motion compensated interpolation process should be able to faithfully reproduce if it is free from artifacts.

The additional hardware requirements needed to implement the invention can be advantageously reduced in preferred embodiments in which said corresponding input image is substantially temporally coincident with an interpolated image from said output interpolator, said test interpolated image being formed by said output interpolator.

In a synchronous, or even an asynchronous, system with differing output and input rates, there will be times at which an output frame is substantially temporally coincident with an input frame. When this occurs, very little, if any, processing is required to produce the output frame from the input frame and the spare hardware capacity within the system can be utilised to perform the above described control operation.

In a synchronous system, there are likely to be times of exact temporal coincidence, whereas in an asynchronous system some sort of thresholding is needed to establish that the frames are substantially temporally coincident to a degree at which a meaningful comparison can be made. A temporal coincidence of perhaps less than 4% of the inter image period might be deemed acceptable.

It will be appreciated that apparatus for performing motion compensated image interpolation is complex and frequently alters an input image in several different ways other than the basic application of motion vector compensated interpolation, e.g. filtering, subsampling, line rate conversion, interlaced to progressive scan conversion etc. In such situations, the interpolator has an effect upon the input image even if no motion vectors are applied. In order to take account of this so as to not produce inappropriate error signals due to other than motion artifacts, preferred embodiments are such that when said output interpolator has a zero motion filtering action, said non motion compensated image is an input image subject to said zero motion filtering action.

As previously mentioned, it is important that there should be

some mechanism for determining when the non motion compensated image and corresponding input image are substantially temporally coincident. A preferred way of dealing with this is to provide a threshold detector for detecting a corresponding input image that is substantially temporally coincident with an interpolated image from said output interpolator as one in which a motion vector of maximum magnitude for said interpolated image multiplied by a value of temporal displacement of said interpolated image from said input image is below a threshold value.

Providing a threshold detector operating in a manner responsive to the maximum magnitude of motion vector within a particular scene allows the system to take account of the degree of motion present when assessing whether the test interpolated image and the corresponding input image are sufficiently temporally close to be deemed temporally coincident, i.e. if a large amount of motion is present, then the images have to be temporally closer so that the comparison is not distorted by genuine differences between the images due to the motion.

The data processing requirements for a system that performs motion compensated image interpolation are high. The amount of image data to be handled and the number of calculations to be performed is typically large. In order to deal with this, it is important that the apparatus should operate at high speed and be efficient. In preferred embodiments of the invention said interpolator includes:

a first multiplier for multiplying pixel values from a first input image by a first temporal weighting coefficient to produce a first partial interpolated pixel value;

a second multiplier for multiplying pixel values from a second input image by a second temporal weighting coefficient to produce a second partial interpolated pixel value; and

an adder for adding said first partial interpolated pixel value and said second partial interpolated pixel value to produce an interpolated pixel value.

With the above form of interpolator for providing the normal interpolation action, it is possible to also use this interpolator to act as the means of subtracting. Accordingly, in preferred embodiments said means for subtracting comprises said first multiplier for multiplying pixel values from said non motion compensated image by a

first subtraction coefficient, said second multiplier for multiplying pixel values from said corresponding image by a second subtraction coefficient that is of equal magnitude and opposite sign to said first subtraction coefficient and said adder for adding outputs from said first multiplier and said second multiplier to form said error signal.

It will be appreciated that the requirement for the subtraction operation is that the first and second subtraction coefficients should be of equal magnitude and opposite sign. An advantageous reduction in the amount of processing required is achieved if these coefficients have a magnitude of unity.

A convenient system for identifying the motion vectors to be used in the motion compensated image interpolation process is to provide:

means for calculating a correlation surface representing image correlation between a search block of image data within a first input image and portions of a temporally adjacent second input image displaced by differing displacement vectors from said search block; and

means for detecting a motion vector corresponding to a point of correlation maximum in said correlation surface.

In such systems, it is usual to provide a mechanism for identifying a correlation maximum in a correlation surface that provides a degree of resistance to problems such as aliasing in the correlation surface. Various tests can be used to this end, their common feature being the provision of some sort of threshold correlation maximum confidence value. The adjustment of this threshold value is a system control parameter that can significantly alter the number of artifacts introduced by the system. Accordingly, in preferred embodiments of the invention said error signal is low pass spatially filtered, said means for adjusting serving to control a threshold correlation maximum confidence value, used by said means for detecting to reject a correlation maximum that is insufficiently clearly characterised, in dependence upon said low pass spatially filtered error signal.

Another system control parameter that has an effect upon the quality of the output is the size of the vector selection block match block used. Accordingly, in preferred embodiments said error signal is high pass spatially filtered, said means for adjusting serving to control search block size in dependence upon said high pass spatially

filtered error signal.

It will be appreciated that motion compensated image interpolation systems are complex and the manner in which a control parameter should be adjusted to reduce the artifacts is not immediately apparent. If the detected error signal increases, it may be that for some images an increase in vector selection block match block size is required whereas for other images a decrease is required. In order to deal with this, in preferred embodiments said means for adjusting performs test adjustments to a control input to produce a first test error signal from a test higher control input value and a second test error signal from a test lower control input value, said first test error signal, said second test error signal and a current error signal from a current control input value being compared to identify that control input value to be adopted as yielding a lower error.

In this way, the means for adjusting adopts a trial-and-error approach to determine which way a control input value should be adjusted.

One way of operating such a trial-and-error system is to rely upon the relative infrequency of scene changes and slow change within a scene and provide that said means for subtracting forms said first test error signal, said second test error signal and said current error signal from three sequential non motion compensated image and test interpolated image pairs. These test error signals are compared and a decision made as to the best system parameter before a change to the system parameter used for generating output images is made.

Thus, if temporal coincidence occurs at every five output frames, then the original error signal will be derived at output frame 0, the first test error signal at output frame 5 and the second test error signal at output frame 10.

An alternative approach is to derive the current error signal, the first test error signal and the second test error signal at the same time. This may be achieved in embodiments in which said means for subtracting forms said first test error signal, said second test error signal and said current error signal from a repeated portion of a single non motion compensated and test interpolated image pair.

Each of the error signals is derived from the same sub-portion of the image so that differences do not arise due to image scene

differences. Thus, in some embodiments a central third of an image scene may be used for each of the three error signal derivations.

On a more general level, it will be appreciated that the error signals and the subtraction analysis described above may be performed over a portion of the images concerned rather than the full images even outside of the context of this particular preferred feature. Furthermore, the invention is equally applicable to both frame based and field based systems.

As previously discussed, one class of embodiments of the invention perform the subtraction to derive the error signal at times when an output interpolation image happens to coincide with an input image. In another class of embodiments it may be preferred that there is provided a test interpolator for interpolating said test interpolated image from at least one interpolated image passed from said output interpolator.

In this way, rather than waiting for the temporal coincidence to occur, the test interpolator generates a test interpolated image that is temporally coincident with an input image from those interpolated images produced by the output interpolator. Accordingly, the feedback control may be made continuously operable and faster acting.

In some embodiments it may be advantageous to reduce the amount of hardware required by providing that said test interpolator acts in dependence upon those motion vectors used by said output interpolator. An alternative that is able to deal with errors that might otherwise be masked by the projection/interpolation back to the input image times is to provide that said test interpolator operates using a different algorithm from said output interpolator and detects its own motion vectors.

In addition to the adjustment of control parameters for the threshold and search block size discussed above, a control parameter may be provided that serves to control reworking of an interpolated image where errors are detected. Accordingly, in preferred embodiments means for adjusting provides a control input that acts to switch generation of an error portion of an interpolated image for which said error signal is unacceptable to a further output interpolator that generates an alternative interpolated image portion to replace said error portion.

With this preferred feature, should errors occur in a particular error portion of an image, then it is possible to use the feedback to switch those error portions to be reworked, possibly using different vectors or with different search block size so as to improve the image quality at the error portion.

As discussed above, it is not always immediately apparent which way the control inputs to the system should be adjusted to improve image quality. This also applies to the reworking of the image. Accordingly, in preferred embodiments there is provided a further test interpolator for interpolating at least a further test interpolated image portion at a temporal position substantially coincident with said non motion compensated image using said alternative interpolated image portion;

further means for subtracting at least a portion of said non motion compensated image from at least said further test interpolated image portion to form a further error signal; and

means for controlling said switching in dependence upon a comparison of said error signal and said further error signal.

The provision of the further test interpolator and further means for subtracting allows the quality of the reworked error portion to be compared with that originally produced and only substituted in its place should there be an improvement.

When reworking error portions of an image, it is possible to introduce disturbing edge effects at the interface between the reworked and the non reworked portions that negate any improvement in image quality that is being sought. In order to reduce this, it is preferred that said alternative interpolated image portion from said further output interpolator and said interpolated image from said output interpolator are combined together using a weighting function centred upon said error block that decreases that contribution from said alternative interpolated image portion and increases that contribution from said interpolated image upon moving away from said error block.

Viewed from another aspect this invention provides a method of generating motion compensated output images at an output rate from input images at an input rate, said output rate being different from said input rate, said method comprising the steps of:

generating interpolated images at said output rate from

temporally adjacent input images in dependence upon image motion vectors;

subtracting at least a portion of a non motion compensated image, taken from a corresponding input image, from at least a portion of an substantially temporally coincident test interpolated image to form an error signal; and

adjusting control inputs to said apparatus in dependence upon said error signal.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 illustrates the relative timing of input and output images;

Figure 2 illustrates apparatus for interpolating an output value between temporally adjacent input images;

Figure 3 illustrates the use of the apparatus of Figure 2 to provide an error signal measuring system performance;

Figure 4 illustrates a system of which the apparatus of Figures 2 and 3 forms part;

Figure 5 illustrates the image sequential trial-and-error approach to adjusting a control value;

Figure 6 illustrates the concurrent trial-and-error approach to adjusting a control value;

Figure 7 illustrates a problem that can occur in finding the best setting for a control value;

Figure 8 illustrates a real time standards converter employing an alternative approach to that previously illustrated;

Figure 9 illustrates a non-real time version of the embodiment of Figure 8;

Figure 10 illustrates forward projection from output interpolated images to test interpolated images;

Figure 11 illustrates backward projection from output interpolated images to test interpolated images;

Figure 12 illustrates a circuit for extracting an error signal utilising both forward and backward projection;

Figure 13 illustrates a weighting function for the mixing together of reworked and non-reworked image portions; and

Figure 14 illustrates a circuit utilising the weighting function

of Figure 13 to mix together reworked and non-reworked image portions.

Figure 1 illustrates the relative temporal positions of a sequence of input images 2 and output images 4. It will be seen that the group of six input images 6 maps to the group of five output images 8. Such a mapping could correspond to a 60Hz to 50Hz format conversion.

The case illustrated is a synchronous arrangement. In this case, each fifth output image 10, 12 is temporally coincident with a corresponding input image 14, 16. The relative temporal positions of the output images 4 within the period between two input images 2 is illustrated at the bottom of the figure. In this synchronous system, the positions are t=0, 0.2, 0.4, 0.6 and 0.8. In a non-synchronous system the relative temporal positions would be unlikely to have such round number values, but nevertheless the same effect would be seen whereby in moving through the sequence of output images 4, periodically an output image would arise that was substantially temporally coincident with a corresponding input image.

For the output images that are not temporally coincident with input images, a motion compensated interpolation between the temporally adjacent input images is made to derive the input image. Considering the output image 18, this is formed by a forward projection of the vectors (indicated by +v) from input image 20 and a backward projection of the vectors (indicated by -v) from input image 22. The relative temporal position between the input images 20, 22 is t=0.2 and so the contribution from the input image 20 is weighted to have more account than that from the input image 22. This is a linear weighting whereby the contribution from input image 20 is multiplied by 0.8 and that from the input image 22 is multiplied by 0.2; other weightings, such as a cosine weighting, are possible.

Figure 2 illustrates part of the apparatus for performing the motion compensated interpolation operation illustrated in Figure 1. Temporally adjacent input images are input along the signal lines present video and next video. These are fed to respective vector application and interpolation units 24, 26. The motion vectors identified between the temporally adjacent input images are also supplied to these units. When a particular pixel value in an output interpolated image is to be derived, the motion vector for that point

is applied as a backward projection in the vector application and interpolation unit 26 and a forward projection in the vector application and interpolation unit 24. These vector applications are also weighted depending upon the relative temporal position of the output interpolated image between the two input images as indicated by the vectors v.t and v(1-t).

The pixel values pointed to by the backward and forward projected vectors within the input images are then fed to respective first and second multipliers 28, 30. These multipliers then weight the pixel values according to the temporal proximity of the output interpolated image (as indicated by the weighting coefficients (1-t) and t, before feeding their outputs to an adder 32 from which an output interpolated pixel value is supplied.

Figure 3 illustrates a modification to the embodiment of Figure 2 to derive an error signal. In this form of operation, the output interpolated image is substantially temporally coincident with the input image on the present video input line. Accordingly, the system output can be tapped from the output of the multiplier 28. This output has then been subject to the same filtering and other operations except the addition by the adder 32 that normally occur during motion compensated interpolation. Alternative taps for the system output could be taken from between the vector application and interpolation unit 24 and the multiplier 28 or, with the use of an equalising delay unit 34, from upstream of the vector application and interpolation unit 24.

The motion vectors between the temporally adjacent input images on the present video signal line and the next video signal line are supplied to the vector application and interpolation units 24, 26. Since the temporal position t is substantially zero, the vector application and interpolation unit 24 has effectively zero motion compensation action. However, the vector application and interpolation unit 26 backward projects to effectively the full extent of the motion vectors to generate what should correspond to the system output (non motion compensated image).

The multipliers 28 and 30 are supplied with respective weighting coefficients of +1 and -1. These coefficients, in conjunction with the action of the adder 32 serve to provide a means for subtracting a test

interpolated image output from the multiplier 30 from a non-motion compensated image output from the multiplier 28. The output from the adder 32 corresponds to an error signal indicating the difference between what should have been interpolated and what was interpolated. If the interpolation was free from artifacts and entirely accurate then the error signal would be zero for all points within the output image. In reality, the error signal is non-zero.

In a synchronous system, which is forced to lock such that temporal positions of zero occur, this analysis can be performed on a regular basis, e.g. a 60Hz to 50Hz converter will have the zero temporal position every five output fields (100ms). In an asynchronous system, this technique can still be applied, but the zero position will occur infrequently. It is possible to increase the frequency of analysis at the expense of output temporal smoothness by treating temporal positions near t=0 (e.g. at approximately t<0.04) as if they were at t=0. A refinement of this approach is to access the highest magnitude motion vector for an output image (available from the earlier processing that extracts the motion vectors) and multiply this by the temporal position of the output image. The result is compared with a threshold value to determine whether the combined effects of the relative temporal position and the amount of motion present in the image indicate that the output is substantially temporally coincident with the input so as to yield a meaningful error signal.

Figure 4 illustrates a system of which the apparatus of Figures 2 and 3 forms part. The system comprises a standards converter 34 including an interpolator stage 36 that provides a system output upon the line 38 formed of output interpolated images and images tapped from downstream of the multiplier 28 during analysis of system performance, as shown in Figure 3. The error signal of Figure 3 is fed to error filters 40 where it may be subject to various filtering operations, e.g. low pass spatial filtering and high pass spatial filtering. The filtering operations may be non-linear, for example, to perform thresholding to remove errors below a certain value, or exponential weighting to increase the contribution of high contrast errors. The output or outputs from the error filter 40 are fed to a summation unit 42 where they are summed over a complete output image. A system performance figure (SPF) for that image can then be fed to a control

system 44 that provides control inputs to the standards converter 34.

The error field derived from the error signal can be analysed by low pass filtering to yield information on large areas of error. This can be used to control the threshold used in vector estimation so as to select how clearly defined a correlation maximum must be before it is used as a source of a motion vector. In addition, or alternatively, the error signal may be high pass filtered to yield information on small areas of error. This information can be used for the control of vector selection block match size used in motion vector identification of the known type.

The direction in which a control parameter should be moved to reduce the amount of error present is not always apparent and amongst other things may depend upon the nature of the image currently being processed. Figures 5 and 6 illustrate two different approaches for dealing with this. Figure 5 relates to the conversion illustrated in Figure 1 whereby a point of temporal coincidence between an input image and an output image occurs for every fifth output image. Given that a control value is set to have a value α, this is used for output frame 0 to derive a system performance SPF_o, at output frame 5, an alternative test control value $\alpha+\delta$ is tried and yields a system performance figure SPF_5. This process is repeated at output frame 10 except that the control value this time is set to $\alpha-\delta$.

When these three system performance figures have been derived for sequential non-motion compensated and test interpolated image pairs, then the control value setting that gave the lowest error signal (system performance figure) can be chosen for subsequent use as indicated by the control value β.

Figure 6 illustrates an alternative approach whereby concurrent trial-and-error assessments are made. In this case, a central portion of the non-motion compensated and test interpolated image pair are compared. Since only a portion of the images are compared, processing capacity is freed up such that the three comparisons for $\alpha-\delta$, α and $\alpha+\delta$ can be made concurrently. This may be achieved by reading the appropriate pixel values from an input frame store through the apparatus of Figure 3 using read addresses that trace through the portion of the image to be tested. When the three trial-and-error comparisons have been made the new setting β is chosen as that giving

the lowest system performance figure.

Figure 7 illustrates a problem which may occur in a system in which more than one minimum is present in the function of system performance figure versus system setting being controlled. In such a case, it is possible that the system will identify and hold itself at a system performance figure minimum that is not the lowest that could be achieved. In order to counteract this, the system may be arranged to periodically choose a trial-and-error setting that differs considerably from that currently being used in an attempt to break away from any false minima that may currently be being used.

Figure 8 illustrates an alternative embodiment in which a test interpolator is provided for interpolating the test interpolated image from at least one interpolated image passed from the output interpolator. In this way analysis of the system performance can be continuously monitored rather than only when an output image coincides with an input image. Thus, an input video signal is supplied to a main standards converter 46 that includes the output interpolator that acts as the primary interpolator for the system. The input video signal is also passed via equalizing delay units 48, 50 to an error analysis unit 52 and an error reduction unit 54. The error analysis unit 52 is passed the motion vectors for each pixel used by the main standards converter 46 in synchronism with the arrival of the input video via the equalising delay unit 48. The error analysis unit 52 also receives the interpolated images output from the mains standards converter 46.

These interpolated images are projected to be temporally coincident with the input images from which they were derived using the supplied motion vectors. If the interpolation processes have been free of artifacts, then the original input images should be regenerated from the interpolated images output by the main standards converter 46 and no difference will be observed when the error analysis unit 52 subtracts these images. When artifacts are present, then the error signal produced by the subtraction in the error analysis unit 52 indicates this.

The error reduction unit 54 receives the input image via the equalizing delay units 48, 50 and serves to perform a further output interpolation in an attempt to produce a better result for the particular parts of the image concerned than was achieved by the main

standards converter 46. The error analysis unit 52 identifies the appropriate error portions of the image in which errors have occurred. This information is then used elsewhere in the circuit to generate alternative parameter control values that have been appropriately adjusted on the basis of the trial-and-error analysis.

The error portion which the error reduction unit 54 has attempted to repair in addition to a corresponding selected portion of the input video is supplied to a secondary error analysis unit 56. This secondary error analysis unit 56 includes a further test interpolator for projecting the attempted repair patch for the error portion back onto the corresponding portion of the input video from which it is then subtracted by a further means for subtracting analogous to that in the main error analysis unit 52. The difference between these two signals forms a further error signal that may be compared with the original error signal from the error analysis unit 52 to determine whether the attempted repair by the error reduction unit 54 has produced a better or worse result. Control values for the main standards converter 46 may also be adjusted by an output from the secondary error analysis unit 56.

A mixer 58 receives both the original output interpolated images from the main standards converter 46 via a temporal delay line 60 and the repair patches for the error portions from the secondary error analysis unit 56. If the repair portions are of better quality than those produced by the main standards converter 46, then the mixer 58 selects these for output. Otherwise, the output is taken from the main standards converter 46.

The overall operation of the embodiment of Figure 8 is such that the main standards converter 46 produces motion compensated output video. This output video is fed to the error analysis unit 52 along with the vector selected for each output pixel. The error analysis unit 52 then generates video (by extrapolating the video and vectors) coincident with the "input" video. This video may be referred to as a reference video. The reference video is then compared to the actual input video, the areas of significant difference indicating where the main standards converter 46 is generating errors.

The areas flagged in the error analysis unit 52 can then be reworked (with changed or steered parameters from those originally

used) in the error reduction unit 54 that is effectively a second smaller standards converter. An example of a parameter that could be changed is the threshold used in vector estimation. An example of a steered parameter could be that those vectors at pixel positions that caused errors are masked off from the vector selection process when this is repeated within the error reduction unit 54.

The reworked video from the error reduction unit 54 is fed to a secondary error analysis unit 56 where it is used to generate reference video that can be compared to the input video. If this reworked video produces less errors than the original output, then it is passed to the output mixer 58. The parameter changes that have produced this improved output may also be passed to the main standards converter 46.

The output mixer 58 combines the reworked areas of the video with the original output from the main standards converter 46.

The size of the error reduction unit 54 need not be prohibitive. If typically only 10% of the picture at worst needs reworking, then the error reduction unit 54 need only be designed to cope for 10% of the data that the main standards converter 46 handles. The error reduction unit 54 can preferably be made to operate with completely different algorithms from that of the main standards converter 46, for example the vector estimation process in the error reduction unit 54 can be phase correlation based while that in the main standards converter 46 can be block matched based.

Figure 9 illustrates an off-line version of the embodiment of Figure 8. Video tape recorders 62, 64 provide storage for input images and output images from the system. The input images to be interpolated are fed to a main standards converter 66 via an input temporal delay unit 68 that is able to store at least two input images. The main standards converter 66 interpolates the input images to output images that are fed to an output mixer 70. The input images and the interpolated output images are also fed to an error analysis unit 72 in addition to the vectors for each output pixel.

The error analysis unit 72 projects the output interpolated images back to the input image temporal positions and performs a subtraction to derive an error signal indicative of artifacts in the output interpolated images. If such artifacts are found, then the error analysis unit 72 controls the main standards converter 66 to

rework those error portions using the input images temporarily stored in the input temporal delay unit 68. These reworked portions can then be mixed with the rest of the image in the output mixer unit 70 before being fed to the output video tape recorder 64.

The embodiment of Figure 9 can be considered as a simplified version of that required for on-line generation illustrated in Figure 8. The input to the system is processed by the mains standards converter 66, whose output is fed to the error analysis unit 72 and the output mixer 70.

The error analysis unit 72 uses the interpolated image video and the vectors it receives for each output image pixel to generate reference frames of video that are compared to the input image video. If after this comparison an error signal exceeding a specified threshold is found, then the corresponding error portions of the output video are reworked.

When areas are to be reworked, the input image video required is replayed through the main standards converter 66 either from the video tape recorder 62 or from the optional input temporal delay unit 68. The main standards converter 66 now performs the function of the error reduction unit 54 of Figure 8. In this case, the mains standards converter 66 is designed to cope with full sized video data and so when working as an error reduction unit many more parameter variations can be tried within the capacity of the hardware. If it is assumed that only 10% of the video at worst may require reworking, then the capacity of the main standards converter 66 would mean that ten variants of the system parameters could be tried to find one that produced better results. When the video has been reworked by the main standards converter 66, it re-enters the error analysis unit 72 where it is interpolated back to the input image temporal positions and used to derive an error signal. If the reworked video is better than the original video, then it is selected and mixed with that previously stored in the output mixer 70. The parameters changes that have produced this improved output can then be adopted by the main standards converter 66 for that portion of the image. In this way it is possible to operate the convertor with different system control parameters for different portions of the image to be converted on the basis of what provides the best results.

Figures 10 and 11 illustrate the generation of reference images/test interpolated images from the output interpolated images. In Figure 10, the output interpolated images are forward projected to times coincident with input images. In Figure 11, the output images are backward projected to times coincident with input images.

Figure 12 illustrates a circuit for deriving the error signal using forward and backward projected images. The input image video is fed to the standards converter 74 where the output interpolated images are generated. The forward and backward projection units 76, 78 then perform the respective processes illustrated in Figures 10 and 11 to produce the test interpolated images. Subtractors 80, 82 produce a difference between these reference images projected to temporally coincident positions with the input images using the input image video signal fed via an equalising delay unit 84. The outputs from the subtractors 80, 82 are fed to filter and summation units 86, 88 where they are subject to the sort of filtering operations previously discussed in relation to the embodiments of Figures 2 to 4 prior to being combined by an adder 90 to yield the error signal.

Figure 13 illustrates a weighting function that can be used to mix together the originally interpolated and the reworked interpolated image in the mixers 58, 70 of Figures 8 and 9 to avoid noticeable edge effects. The weighting functions varies between a value of unity at the centre of the error portion to a value of zero far from the error portion. The weighting function is dependent upon the x, y coordinates measuring the displacement from the centre of the error portion.

Figure 14 illustrates the operation of the mixers 58, 70 of Figures 8 and 9. The original and reworked blocks are fed to respective multipliers 92, 94 where they are multiplied by the complement of the weighting function and the weighting function respectively prior to being passed to an adder 96. At the centre of the reworked block, the output is derived fully from the reworked block. Distant from the centre of the reworked block, the output is derived fully from the original block. In this way, a smooth transition between the reworked data and the original data can be provided.

CLAIMS

1. Apparatus for generating motion compensated output images at an output rate from input images at an input rate, said output rate being different from said input rate, said apparatus comprising:

an output interpolator for generating interpolated images at said output rate from temporally adjacent input images in dependence upon image motion vectors;

means for subtracting at least a portion of a non motion compensated image, taken from a corresponding input image, from at least a portion of an substantially temporally coincident test interpolated image to form an error signal; and

means for adjusting control inputs to said apparatus in dependence upon said error signal.

2. Apparatus as claimed in claim 1, wherein said corresponding input image is substantially temporally coincident with an interpolated image from said output interpolator, said test interpolated image being formed by said output interpolator.

3. Apparatus as claimed in any one of claims 1 and 2, wherein said output interpolator has a zero motion filtering action, said non motion compensated image being an input image subject to said zero motion filtering action.

4. Apparatus as claimed in any one of claims 2 and 3, comprising a threshold detector for detecting a corresponding input image that is substantially temporally coincident with an interpolated image from said output interpolator as one in which a motion vector of maximum magnitude for said interpolated image multiplied by a value of temporal displacement of said interpolated image from said input image is below a threshold value.

5. Apparatus as claimed in any one of claims 2, 3 and 4, wherein said interpolator includes:

a first multiplier for multiplying pixel values from a first input image by a first temporal weighting coefficient to produce a

first partial interpolated pixel value;

a second multiplier for multiplying pixel values from a second input image by a second temporal weighting coefficient to produce a second partial interpolated pixel value; and

an adder for adding said first partial interpolated pixel value and said second partial interpolated pixel value to produce an interpolated pixel value.

6. Apparatus as claimed in claim 5, wherein said means for subtracting comprises said first multiplier for multiplying pixel values from said non motion compensated image by a first subtraction coefficient, said second multiplier for multiplying pixel values from said corresponding image by a second subtraction coefficient that is of equal magnitude and opposite sign to said first subtraction coefficient and said adder for adding outputs from said first multiplier and said second multiplier to form said error signal.

7. Apparatus as claimed in any one of the preceding claims, comprising:

means for calculating a correlation surface representing image correlation between a search block of image data within a first input image and portions of a temporally adjacent second input image displaced by differing displacement vectors from said search block; and

means for detecting a motion vector corresponding to a point of correlation maximum in said correlation surface.

8. Apparatus as claimed in claim 7, wherein said error signal is low pass spatially filtered, said means for adjusting serving to control a threshold correlation maximum confidence value, used by said means for detecting to reject a correlation maximum that is insufficiently clearly characterised, in dependence upon said low pass spatially filtered error signal.

9. Apparatus as claimed in any one of claims 7 and 8, wherein said error signal is high pass spatially filtered, said means for adjusting serving to control vector selection block match block size in dependence upon said high pass spatially filtered error signal.

10. Apparatus as claimed in any one of the preceding claims, wherein said means for adjusting performs test adjustments to a control input to produce a first test error signal from a test higher control input value and a second test error signal from a test lower control input value, said first test error signal, said second test error signal and a current error signal from a current control input value being compared to identify that control input value to be adopted as yielding a lower error.

11. Apparatus as claimed in claim 10, wherein said means for subtracting forms said first test error signal, said second test error signal and said current error signal from three sequential non motion compensated image and test interpolated image pairs.

12. Apparatus as claimed in claim 10, wherein said means for subtracting forms said first test error signal, said second test error signal and said current error signal from a repeated portion of a single non motion compensated and test interpolated image pair.

13. Apparatus as claimed in claim 1, comprising a test interpolator for interpolating said test interpolated image from at least one interpolated image passed from said output interpolator.

14. Apparatus as claimed in claim 13, wherein said test interpolator acts in dependence upon those motion vectors used by said output interpolator.

15. Apparatus as claimed in claim 13, wherein said test interpolator operates using a different algorithm from said output interpolator and detects its own motion vectors.

16. Apparatus as claimed in any one of the preceding claims, wherein said means for adjusting provides a control input that acts to switch generation of an error portion of an interpolated image for which said error signal is unacceptable to a further output interpolator that generates an alternative interpolated image portion to replace said error portion.

17. Apparatus as claimed in claim 16, comprising:

a further test interpolator for interpolating at least a further test interpolated image portion at a temporal position substantially coincident with said non motion compensated image using said alternative interpolated image portion;

further means for subtracting at least a portion of said non motion compensated image from at least said further test interpolated image portion to form a further error signal; and

means for controlling said switching in dependence upon a comparison of said error signal and said further error signal.

18. Apparatus as claimed in any one of claims 16 and 17, wherein said alternative interpolated image portion from said further output interpolator and said interpolated image from said output interpolator are combined together using a weighting function centred upon said error block that decreases that contribution from said alternative interpolated image portion and increases that contribution from said interpolated image upon moving away from said error block.

19. A method of generating motion compensated output images at an output rate from input images at an input rate, said output rate being different from said input rate, said method comprising the steps of:

generating interpolated images at said output rate from temporally adjacent input images in dependence upon image motion vectors;

subtracting at least a portion of a non motion compensated image, taken from a corresponding input image, from at least a portion of an substantially temporally coincident test interpolated image to form an error signal; and

adjusting control inputs to said apparatus in dependence upon said error signal.

20. Apparatus for generating motion compensated output images substantially as hereinbefore described with reference to the accompanying drawings.

21. A method of generating motion compensated output images

substantially as hereinbefore described with reference to the accompanying drawings.

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Databases (see over)

(i) UK Patent Office

(ii)
ONLINE DATABASES: WPI

Search Examiner

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Documents considered relevant following a search in respect of claims 1-21

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

SF2(p)

JF - doc99\fil002311

Category	Identity of document and relevant passages -24-	Relevant to claim(s)

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